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An Overview of Automaticity and Implications For Training the Thinking Process

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This report examines the relationship between automaticity and thinking processes. Issues pertaining to the development of automaticity within the thinking process are discussed. A literature review was conducted to examine how automaticity has been developed in various tasks of all types (e.g., visual search to battlefield thinking). The results of this examination suggest that automaticity can be developed using consistent rules and extensive practice that vary depending on the type of task. The results also suggest that the more complex the task is the more difficult it will be to train to automatic performance. Principles are presented that are used to guide the development of automaticity. Using these principles, along with previous methodologies for developing automaticity, this report discusses training methods for developing automaticity in the thinking process.

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FOREWORD

Improvements in Army training and evaluation are an enduring concern of the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI). That concern is underscored by the Army's ongoing transformation into a future force ready to respond across a full mission spectrum. Such readiness, particularly the ability to make effective decisions quickly and accurately across the full range of missions, requires that more efficient and effective training and evaluation methods be developed and sustained. In coordination with U.S. Army Training and Doctrine Command (TRADOC), ARI has developed programs to train both battlefield thinking and tacit knowledge for leaders. Several of those efforts, in particular the TRADOC's Adaptive Thinking experimental program and the Think Like a Commander programs at the Armor and Combined Arms Schools, have focused on the development of automaticity in thinking processes. In support of those efforts and as part of ARI's program of research for the future force, this report examines the psychological, educational, and training research literature to gain insight into how the concept of automaticity in thinking processes can be used to improve a leader's ability to make effective decisions on the battlefield.

This research was part of ARI's Future Battlefield Conditions (FBC) team efforts to enhance soldier preparedness through development of training and evaluation methods to meet future battlefield conditions. Results of this effort support ongoing work in the FUTURETRAIN (211) work program and were shared with other interested ARI units.

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AN OVERVIEW OF AUTOMATICITY AND IMPLICATIONS FOR TRAINING THE THINKING PROCESS

EXECUTIVE SUMMARY

Research Requirement:

For more than a century psychologists have noted the importance of the process wherein elements of a task become habitual or automatic, thereby reducing the amount of thought and attention required for performance of the overall task. Since those early observations of habits and the influence they have on task performance, much experimental work has been conducted to understand the characteristics of the automatization process and the development of expertise that follows. Several ARI programs are currently working on methods of training battle command expertise, and those efforts directly involve evaluating the process and effects of automatization of higher cognitive behaviors such as understanding, evaluating, deciding, and other such behaviors that can collectively be termed as thinking. Thinking habits are an especially relevant aspect of performance in the stressful and demanding environment of the battlefield. In order to capitalize on the benefits of automatization through the optimizing of training and performance, it is necessary to appreciate the relationships between automaticity, training, and expertise.

Procedure:

The literature concerning skill development was examined across a variety of task types including perceptual, motor, and cognitive tasks and across a variety of disciplines such as: military, psychology, education, and training. The features and principles of habits and the methodologies or procedures used to develop automaticity within each type of task were examined to determine if they were consistent across all three types of tasks. The literature was further examined to determine if there was a consistent method for identifying tasks or components of tasks as being automatic or controlled, and thereby determining which tasks or components are good candidates for training to automatic levels.

Findings:

The major finding within the literature was that consistent practice at some level of a task leads to automaticity. Automaticity facilitates the development of expertise as displayed in the ability to multi-task, increased speed, increased accuracy, immunity to environmental stressors, and greater retention. Another finding was that complex higher-order tasks, such as thinking, usually combine controlled and automatic processing. The problem is determining which components require controlled thinking and which components can become automatized. Nine principles, along with a methodology, were presented as a means of identifying consistencies within a task and then training those consistencies to levels of automaticity. Also, a definition was presented as a means of measuring the extent to which tasks or the components of tasks are automatic or controlled. Therefore, one can determine if a task or component of that task is

automatic or controlled in nature, and then use the nine principles along with the methodology to identify and train the consistent aspects of the task.

It was further found that the benefits of automaticity appear to be consistent across perceptual, motor, and cognitive tasks. That is, the benefits of the ability to multi-task, increased speed, increased accuracy, immunity to environmental stressors, and greater retention appear to be consistently found across different types of tasks. However, the methodologies used to train tasks to automaticity are very different across each type of task. For example, perceptual studies have utilized the visual-search paradigms and vigilance tasks, while motor studies have implemented implicit learning or overlearning strategies, and cognitive studies have used problem-solving methods for assessing automaticity.

The literature also points out that automaticity in motor-skills may operate slightly differently than in perceptual or cognitive areas. The literature has suggested that motor automaticity may operate as a level of control theory, while automatic perceptual or cognitive skills may operate as a level of processing theory. An automatized motor-skill may operate at a level not associated with awareness, or not directly under conscious control, while automatized perceptual or cognitive tasks involve the extent to which information has to be processed to be understood.

Utilization of Findings:

The findings of this report provide a clearer picture of the relationships between automaticity, training, and the building of expertise. Several ARI programs are currently working to train battlefield expertise, and the findings of this report will be shared with these and other interested research units.

AN OVERVIEW OF AUTOMATICITY AND IMPLICATIONS FOR TRAINING THE THINKING PROCESS

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AN OVERVIEW OF AUTOMATICITY AND IMPLICATIONS FOR TRAINING THE THINKING PROCESS

Introduction

In recent years, the U.S. Army Research Institute for Behavioral and Social Sciences (ARI) has made a strong effort to address the issue of adaptive thinking. Adaptive thinking may be defined as: using knowledge and reasoning to make adjustments in the context of a plan during a performance in a domain of expertise. In a military context, it is the thinking that supports a leader when he or she is adapting to unanticipated events, particularly during the execution of military operations. A major part of the difficulty in exhibiting good adaptive thinking on the battlefield is that the environment makes extraordinary demands on the cognitive capability and attention of the leaders. In the challenging environment of the modern battlefield they already have so much to monitor, think about, and do that it is not easy to find additional cognitive resources to recognize and respond creatively to unanticipated events. The problem is not so much a lack of knowledge in the leaders, for they often have a complex, detailed understanding of the battlefield entities resulting from years of study; it is rather a consequence of limited opportunities to apply their knowledge in realistic situations so that the application of their expertise remains effortful and cognitively demanding. If the foregoing assertion is true, the solution to improving adaptive thinking ability is not to be found by providing more knowledge but instead by deliberate practice of sound battlefield thinking until key elements have become automatic.

The Think Like a Commander (TLAC) program comprises a series of efforts that involve using deliberate practice training methods to train components of the thinking process in an attempt to increase the speed in which these components are performed and also to reduce the cognitive resources that are required to perform these components (U.S. Army Research Institute, 2001). The TLAC program involves a series of situational vignettes that place students in the position of battlefield commanders confronted by unexpected events. After students consider each vignette, their thinking is then examined to address the extent to which it employed the thinking behaviors incorporated in eight TLAC themes:

1. Keep a focus on **mission accomplishment** and **higher commander's intent.**
2. Model a **thinking** enemy.
3. Consider effects of terrain.
4. Consider **all elements/systems** available to you and your enemy and their interactions.
5. Include considerations of **timing.**
6. Exhibit visualizations that are **dynamic** and **proactive.**
7. Consider **contingencies and remain flexible**.
8. Consider how your fight fits into **the bigger picture** from friendly and enemy perspectives.

The TLAC themes do not represent novel information to most military leaders; they are little more than an elaboration of the components of mission, enemy, troops, terrain, time (METT-T) and some well-known elements that combine these factors, e.g., visualization. The central concept of the TLAC program is not to teach understanding of these concepts, rather it is to ingrain them in the leader's thinking to such a level that they appear in the demanding

battlefield environment. Further, by training components of the thinking process to levels of automaticity, battlefield commanders should have additional cognitive resources available for the more strategic and complex aspects of the battlefield.

In order to support TLAC and related efforts, this paper reviews research on automaticity, its characteristics, its development, and various methods of training it. This paper also advances a methodology of identifying components of the thinking process, that can be readily trained to levels of automaticity, and determining the best strategy for training these once they are identified.

In his *Principles of Psychology,* James (1890) talked of the idea that certain human processes can become automatic in terms of instinctive reflexes and through habits. Instinctive reflexes are those behaviors that are physiologically "hard-wired." These innate reflexes are behaviors that result from the working of the autonomous nervous system. They are a necessary aspect of survival resulting from natural selection. Habits are the results of repeated experience and this experience can lead to skill development in some behavioral domain. The focus here will be on these "habits" and how experience/practice leads to skill development and may lead to the automatic performance of behaviors or the automatic processing of information.

Huey (1908) also spoke of the effects of practice in regard to the development of reading abilities. He stated that perceiving new words, or acquiring new reading abilities requires a considerable amount of time and will likely be error-ridden at first. However, over time, repetition progressively frees the mind from the amount of attention focused on the details of the task, makes the total task easier to achieve, shortens the time to complete, and reduces the extent to which consciousness must be involved.

Guthrie (1935,1952) accounted for the gradual increases in performance with practice by distinguishing between *Acts* and *Movements*. Acts are the complex responses that we observe and study. Riding a bicycle, driving a car, saying a word, or throwing a ball, are acts. Each of these total acts is made up of many different *movements* (Houston, 1991). For example, a movement in throwing a ball would be gripping the ball, or rotating the shoulder back to prepare to throw. Each movement is learned in one trial, although the mastery of the total set of movements may require many trials. To master the total complex act, many different responses must be connected to many different stimulus configurations. Guthrie (1935,1952) stated that the gradual improvements with practice that are observed are the result of a growing number of learned movements, each of which is acquired in all-or-none fashion. To Guthrie the performance of behaviors and the creation of habits were inextricably linked; what one did became a habit, and habits could be created only by performance.

Further examining the effects of practice on performance and the acquisition of skill, Schneider and Shiffrin (1977), among others, have experimentally distinguished between two types of qualitatively different forms of processing: controlled and automatic. Controlled processes are those strategic processes required for novel tasks or those tasks requiring the devotion of attention. Controlled processes have been considered serial in nature and are carried out in a stepwise fashion. They have also been thought to be carried out much like a recipe, do this- then this, etc. Controlled processes have been described as being performed more slowly

and under the explicit control of the individual. After much consistent practice, some tasks no longer require the devotion of attentional resources and are performed to completion in the presence of the initiating stimulus unless there is a conscious effort to inhibit them. Automatic processes are characterized by this decrease in the cognitive/attentional resources allocated for these tasks. This is facilitated by the parallel processing of the automatic task with other more controlled processes, allowing multi-tasking or the performance of controlled tasks in parallel to the automatic task.

However, almost all behavior is going to be some combination of both automatic and controlled process. Rarely will a behavior be purely controlled or automatic, except maybe in very artificial laboratory settings. Most behaviors will involve multiple processes and components, some of which will be automatic and some that will be controlled (Shiffrin & Dumais, 1981). A process may, however, be largely automatic or controlled, and it would be greatly beneficial to determine which, in order to train or develop skill at the task. One way to do this is may be to divide a task into its subcomponents (similar to the idea of acts and movements) and then evaluate these as to determine the extent to which they are automatic or controlled and thereby determine the extent to which the overall task is automatic or controlled. In order to do this, there needs to be a set of identifiable and measurable characteristics to evaluate these subcomponents with. Although, categorizing a subcomponent as automatic or controlled is not always a clear-cut task. For instance, a subcomponent of a task may be initiated by a controlled process and then proceed automatically from then on. An example of this is the turning of the steering wheel to pull a car into a store's parking lot. The act of thinking about entering the store may be the controlled process that activates the automatic process of turning the wheel (Shiffrin & Dumais, 1981). The challenge is to identify measurement techniques that will have the ability to identify controlled processes from those automatic processes that are only initiated by controlled processes.

Automaticity of Perceptual Tasks

This section examines the psychological literature dealing with automaticity of perceptual tasks. The bulk of the research deals with development of automaticity in lower order tasks (e.g., visual search paradigm). Table 1 adapted from Samuels and Flor (1997) lists the proposed benefits and limitations of automatic processing.

Table 1

Benefits and Limitations of Automatic Processing

Benefits	Limitations
• Performance is fast and accurate, with a minimum of attentional demands. • Attentional energy is available for other types of processing, especially higher-order processing that cannot be automatized.	• Automatic level comes after extended practice, which requires diligence on the part of the learner. • Thought/action becomes non-conscious; difficult to control (e.g., Stroop Effect).

Table Continues

• Multi-task functioning (e.g., reading and driving). • Greater retention of learned material. • Performance becomes immune to effects of stress, alcohol, fatigue, and vigilance situations.	• Difficult to suppress or modify automatic behaviors. • Difficult to analyze or explain to others the separate components of automatized skill.

Fast and accurate performance with minimal attentional demands is the first benefit. For example, when an adult is asked a simple addition question they are able to answer very quickly and accurately without much effort. The next benefit is having attentional energy available for other types of processing. In other words, when a person experiences an unfamiliar situation they will have attentional resources available to address this situation because lower order tasks are automatic. The third benefit provided by Samuels and Flor (1997) is multi-task functioning. Multi-task functioning allows an individual to engage in several activities simultaneously. An experienced driver, for example, can simultaneously control his vehicle and navigate. Furthermore, when navigating in familiar territory, most drivers have sufficient mental resources remaining to think about any number of other topics, and on a routine route can perform with little or no conscious attention. The next benefit mentioned is greater retention of learned material. Fisk and Hodge (1992) assessed retention levels of automatic processes and found that they were maintained even after long periods of disuse (e.g., one year after use). The last benefit discussed is that performance becomes resistant to the effects of stress, alcohol, fatigue, and vigilance situations. For example, when individuals are fatigued while driving, many times they are able to reach their destination safely without recollection of how they arrived there.

The first limitation is that automatic levels come only after extended practice, which requires diligence on the part of the learner. The problem is that many individuals may not have the time and patience to practice for extended periods of time. The second limitation is that thought or actions that have become non-conscious are difficult to control. The Stroop Effect is a prime example of this limitation. The classic study done by Stroop (1935) revealed that participants had difficulty naming the print color of a word if the word itself was a different color (e.g., the word blue written in yellow ink). The automatized behavior of reading interfered with the color-naming task. The next limitation is similar; automatic behaviors are difficult to suppress or modify. For example, many people have difficulty suppressing the behavior of pressing the clutch with their foot, once it becomes automatic, even when they drive an automatic transmission vehicle. The last limitation listed is difficulty in analyzing or explaining to others the separate components of automatized skill. For example, it is rather difficult to explain how to tie a shoe but the actual process can take less than 10 seconds. These limitations demonstrate that automaticity is not as trouble-free as it may seem. When training to automatic levels the limitations should be addressed.

Expertise literature with regard to automaticity needs to be examined to ascertain how expertise and automaticity are related. Expert behavior demonstrates many of the benefits of automaticity. Glaser and Chi (1988) summarized the differences between novice and expert performance which is located in Table 2.

Table 2

Characteristics of Expertise

1. Experts excel mainly in their own domains.

2. Experts perceive large meaningful patterns in their domain.

3. Experts are fast; they are faster than novices at performing the skills of their domain, and they quickly solve problems with little error.

4. Experts have superior short-term and long-term memory (for material in their own domains of expertise).

5. Experts see and represent a problem in their own domain at a deeper (more principled) level than novices; novices tend to represent a problem at a superficial level.

6. Experts spend a great deal of time analyzing a problem qualitatively.

7. Experts have strong self-monitoring skills.

There is one important implication that arises from these characteristics. Experts experience events, including their own actions, in their domains of expertise differently than novices. Furthermore, Chase and Simon (1973) demonstrated experts' perception of and memory for meaningful patterns in their domain and such results suggest that the contents of mental states during task performance are different for experts and novices. In the Army, expert commanders can be distinguished from novices if they possess the characteristics from Table 2.

Automatic and Controlled Processing

Shiffrin and Schneider (1977) introduced two processing modes that are the basis for their information processing theory of automaticity. They conducted experiments with the main focus on search and attention tasks to determine the differences in information processing. The results of these experiments indicated that there are two fundamental processing modes: controlled and automatic. Briefly mentioned earlier, controlled processing is usually serial in nature with a limited comparison rate, is easily established, altered, and even reversed, and is strongly dependent on load. Conversely, automatic processing is relatively well-learned in long-term memory, is demanding of attention only when a target is present, is parallel in nature, is difficult to alter, to ignore, or to suppress once learned, and is virtually unaffected by load. Controlled and automatic processing will be examined further and research will be provided to support the existence of both.

Shiffrin and Schneider conducted experiments that contained many elements that could be manipulated depending on the criteria being examined. Each participant was presented with several items that were to be identified on the trials (i.e., *memory-set*). Next, the participants were presented with a *frame* containing varying sets of numbers (1 to 4) and asked to indicate if

any items from the memory-set were located in that frame (i.e., *targets*). The *load* is the product of the memory-set and frame size, which was varied to examine attention capacity. Finally, a *distractor* was an item in the frame that was not in the memory-set.

Shiffrin and Schneider examined the effects of two procedures for producing automaticity in information processing: consistent mapping (CM) and varied mapping (VM). The CM procedure involves memory-set items never being distractors, across all trials, as well as distractors never being memory-set items. For example, the memory-set for the entire set of trials could be *A, B, C, and D* while the distractors are the remaining letters in the alphabet. The VM procedure involves memory-set items and distractors being randomly mixed over all trials. For example, *A, B, C, D* could be memory-set items for the first trial while the remaining alphabet are distractors. On the second trial *E, F, G, H* could be memory-set items while the remaining alphabet would be the distractors including *A, B, C, D.* In the Shiffrin and Schneider experiment, they used numbers for the memory-set items and consonants for distractors in the CM procedure to make the targets more easily detectable. Conversely, they used consonants for both the memory-set and distractors in the VM condition. They examined the effects of frame set size (1,2, or 4), memory-set size (1 or 4), and differences between CM and VM. The dependent variables used were the number or percentage of hits (correct detections) and the number or percentage of false alarms (incorrect detections). The overall findings supported the idea of automatic and controlled processing. The VM conditions demonstrated large effects of load, with both memory-set size and frame size having considerable influence on the level of accuracy. Performance was better in all CM conditions than in the easiest VM condition suggesting that CM is a more effective method for training. Furthermore, the different CM conditions varied minimally with regard to load variations indicating that automatic processing had incurred.

There have been numerous replications (e.g., Myers & Fisk, 1987; Strayer & Kramer, 1994) of the work done by Shiffrin and Schneider that examined similar processes. Myers and Fisk (1987) state that stimulus patterns receiving CM training were processed faster, more accurately, and less variably than those receiving VM training. Strayer and Kramer (1994) found that CM and VM responses regarding accuracy and speed are affected by memory-set composition. During mixed conditions (i.e., items in memory-set drawn from both the CM and VM pool) the CM probes were responded to slower and somewhat more accurately compared to the blocked condition. The VM probes, in mixed conditions, were responded to faster but with less accuracy than in the blocked conditions. These findings demonstrate the critical role of strategic factors in automatic processing. For example, in blocked conditions participants implemented differential strategies for CM and VM conditions. Conversely, during mixed conditions where predicting the probes was not possible they had to adopt a generic strategy for every trial.

The work by Shiffrin and Schneider (1977) was the first major empirical research done concerning automatic and controlled processing. The findings are significant for several reasons. First, they provide concrete differences between automatic and controlled information processing, thus allowing individuals to differentiate between types of processing. Next, they examined consistent and varied mapping strategies and provide evidence as to why consistent

mapping is superior. In general, the Shiffrin and Schneider experiment laid the groundwork for the majority if not all of automatic and controlled processing theories.

Characteristics of Automatic and Controlled Processes

Most complex behaviors, characteristic of experts, will involve a combination of controlled and automatic processing. The ability to identify those aspects of the tasks that are automatic and those that are controlled is a key to effective training. Shiffrin and Dumais (1981) took the results of the early work done with the visual search paradigms and developed twelve characteristics that can be used to distinguish between automatic and controlled processes. Examination of the task against these twelve criteria helps determine the extent to which a task is controlled or automatic in nature. The twelve characteristics of controlled and automatic processes serve then as a definition of the differences between these two processes and are listed below as described by Shiffrin and Dumais (1981).

1. Capacity: The utilization of general processing capacity is a major component of the proposed criterion for distinguishing between automatic and controlled processing. One would simply measure the extent to which a task was limited by cognitive capacity. The more the task was limited by cognitive capacity the more the task was done by controlled processing. This could be measured by the dual-task methodologies, or measuring the extent to which performing co-occurring tasks interferes with the original task.

2. Control: The ability to control a process is used to help define automaticity. That is, some automatic processes may demand attention and thereby use capacity but do so in a mandatory fashion, whenever the appropriate stimulus is presented. Automated components of mixed processes may be initiated by controlled processes, but the process, as a whole cannot be classified as automatic.

The degree of automatism of mixed processes can be assessed on the dimension of control. For the most part, controlled processes are continuously monitored, attended to, and governed by the subject. One partial exception occurs when there is an extremely rapid sequence of controlled processes. The speed apparently makes it difficult for the subject to learn the means of control. Consider the comparison process in VM search tasks; sometimes subjects terminate when a match is found, and sometimes an exhaustive search occurs. The choice seems to be determined by the task requirements, rather than by the will of the subject. However, because subjects can use either mode, they could presumably be trained to use either at their discretion once the means of control had been identified.

When mixed sequences are largely automated, the control is usually concentrated in the initiation phase; once started, such sequences tend to run to completion without further control. This leads to the next characteristic.

3. Continuation: Automatic processes tend to run to completion, unless effort is expended to prevent such an occurrence or unless another automatic process uses the same specific resources. In general, controlled processes can be strung together in a sequence only through continuing

effort. Even when a controlled sequence is quite rapid, as in a VM search, it is clear that capacity and attention are required throughout the process.

4. Indivisibility: Automatic processes tend to occur in units that begin and end at fixed points. Therefore, it may be difficult to begin in the middle of an automatized sequence (e.g., it may be difficult to play a well-learned piano passage by beginning in the middle of the passage). Controlled sequences may be started or ended at the subject's discretion.

5. Practice: Generally, controlled processes do not show much, if any, improvement with practice. Automatic processes often exhibit sustained and dramatic changes with increasing practice. Shiffrin and Dumais (1981) state that the lack of change with practice for a given controlled process must not be confused with the tremendous changes that occur in the choice of a controlled process as learning develops.

6. Modification: A controlled sequence is easily modified to fit new task environments, or instructions. An automatic sequence will tend to reoccur in response to the previously trained initiating stimuli. Retraining of a new automatic sequence can be arduous and more difficult than the initial learning. Evidence in the search domain includes the difficulties of reversing targets and distractors in CM condition (as compared with the ease of changing stimuli in the VM conditions).

7. Serial versus Parallel Processing: Controlled processes tend to operate sequentially (due to capacity demands) whereas automatic processes can operate in parallel, and often independently of other tasks.

8. Learning and Storage: Shiffrin and Dumais (1981) felt that the evidence at the time pointed to long-term storage being produced by controlled processing of some sort. These researchers stated that "incidental learning" can occur, but often through the use of "incidental" controlled processes. They also stated that some storage may occur through the use of automatic processing, but the amount seems to be less than when controlled processing is used. This seems to be in contradiction to the findings of Lane and Robertson (1979), who found evidence for incremental learning in their research of chess masters.

9. Performance level: A complex task can often be accomplished at higher accuracy and faster speed once automatization has occurred. However, this is not the case before learning has occurred and may not be the case for very simple tasks that require very little controlled resources. For example, in the search paradigm, CM search is generally superior to VM search, except in some cases when the load is only one (only a single comparison is required); in this simple case, it is believed that controlled search can sometimes lead to faster reaction times.

10. Clarity of Initiating Stimulation: For automatic processes to operate effectively without numerous errors and false alarms, the ambiguity of the initiating stimulation probably has to be low. For example, we should not expect automatic detection to operate well in search tasks, if the stimulus clarity is dropped to threshold. In this case, the targets, and distractors become ambiguous, and a careful decision may be required for a response.

11. Awareness: Controlled processes generally involve consciousness of the various components. An exception to this may be controlled processes that occur so rapidly that the awareness of the separate components is reduced or masked. Automatic processes do not usually require attention, unless they include an attention-calling component. Shiffrin and Dumais (1981) state that even with this provision, one must be very careful in trying to use awareness or consciousness to classify processes as automatic or controlled. One problem that can arise is that consciousness is often identified with memory, but this is not proper. For example, one can be quite "aware" that one sees all the characters in a briefly presented display of letters, even though few of these can be recalled 2 seconds later. It is possible that some automatic processes might achieve "awareness" in the momentary sense, even if they are not well remembered later. Usually, controlled processes will tend to be remembered (subject to all the well-known limitation on memory, of course). A more important problem lies in the following fact: There is often nothing preventing controlled processes from being assigned in parallel with automatic processes to the same task. The controlled process can be used to monitor the automatic process, thereby producing awareness, or to mimic or supplement the automatic process, thereby producing an awareness of its own.

12. Attention and Intention: Automatic processing allows tasks to be performed as if attention could be divided among many inputs but may sometimes prevent focusing (because extraneous inputs may call attention due to prior training). Controlled processing is generally focused and can be divided only to the degree allowed by capacity limitations. Controlled processing involves intention by the subject (unless it is invoked by an automatic process), whereas automatic processing does not require intention (unless it occurs in a mixed sequence that is automatic except for an initiation that requires a controlled process).

Shiffrin and Dumais (1981) suggested that these characteristics could be used to develop a methodology for assessing the characteristics for an overall job, or for the components of a job. Measuring these characteristics, (the use of dual-task and interference methodologies fit most of the twelve characteristics), allows the automatic components of the job to be identified. Once identified, these automatic components can then be trained to automaticity, thereby freeing additional cognitive resources for the controlled components of the task.

Vigilance

One of the most dramatic examples of the use of automatic processing as a training procedure involves the vigilance decrement. The vigilance decrement refers to the problem of the decline in performance over time during a watch-keeping period when the number of signals to be detected is infrequent. Finding a solution to this decrement problem has puzzled many investigators. Literally thousands of studies have been devoted to this problem because of its implication for areas of work such as radar signal detection, monitoring machine malfunction warning signals, and detection involving product quality control on the assembly line. Fisk and Schneider (1981) were able to eliminate this decrement by automatizing the activity through a training program that presented the stimulus and then required a response. These pairings went on for over 4,000 training trials. This resulted in the automaticity of the response due to this large number of pairings. Later, the trainees performed the real task with only 18 targets presented over 6,000 presentations. Instead of the usual performance decrement occurring, there

was virtually no decrement over time because the responses had become automated and thus required very little attentional capacity from the trainee.

Automatic processes operate without capacity and they therefore neither suffer from nor cause interference. In the research this has been examined in three ways, which differ considerably in how they determine interference effects. The first way is through dual-task experiments where the subject has to carry out two actions simultaneously (e.g., respond vocally to acoustic stimuli while performing a tracking task). The second way is in monitoring and search experiments with only a single task. The processes assumed to occur in parallel are operations performed on simultaneously presented stimuli within the task (e.g., different words presented concurrently to the left and right ear). In the third methodology there is neither simultaneous tasks nor simultaneous stimuli. What is shown to be interference-free in these experiments is the preparation for one stimulus and the response to a different, unprepared stimulus. For example, priming a certain group of semantically related words does not interfere with a lexical decision response to a semantically unrelated word. What the subject does here is perform a choice reaction, which usually consists of pressing one of two buttons, to the appearance of a stimulus, usually a word. Since there is only one task and one stimulus at a time, there can of course, be no interference between simultaneous processing operations. However, preparation might disturb processing if the stimulus actually presented is different from what the individual was prepared (primed) to process. The absence of this kind of disruption is taken to indicate interference-free processing (Neumann, 1984).

Retention of Automatic Perceptual Processes

Overlearning or over-trained individuals are often shown to demonstrate greater retention compared to control groups. Overlearning is defined as practice of a skill beyond 100% accuracy or beyond successful performance, defined by some predetermined criteria (Baldwin & Ford, 1988). Healy, Fendrich, and Proctor (1990) examined the issue of acquisition and retention of a letter-detection skill. There were three groups that the participants were assigned to: (1) extensive detection training, (2) limited detection training, and (3) no detection training. They presented participants with a 16-letter string and provided detection training (amount depending upon assigned group) for a specific target (e.g., the letter H). The findings indicate that when given sufficient training to produce automaticity, those skills will be retained for long periods of time (e.g., 1 month). Healy et al. (1990) replicated this study only using two participants to examine the retention of detection skills over a longer period of time (e.g., 6 and 15 month intervals). The results suggest that there was not a significant decline in detection performance for the greater length of time.

Fisk and Hodge (1992) also conducted several experiments addressing this issue. They found a nonsignificant decay in performance, after a month delay from the end of experiment, when examining a pure visual search, which replicates Healy et al. (1990). Alternatively, they found a significant delay in performance when measuring a hybrid memory/visual task (i.e., participants searched a display of nine letters for any one of five memory-set items) after a month delay. These findings suggest that for perceptual tasks there is less decay in performance compared to cognitive tasks.

Fisk, Hodge, Lee, and Rogers (1990) examined the issue of retention with regard to complex skills such as those related to an air traffic controller. They trained four groups (i.e., high amount of CM training, moderate amount of CM training, low amount of CM training, and VM training) in search condition and memory-set size variations and recorded reaction times and errors committed. They determined that the varying amounts of training had succeeded in differentiating the skill level of the groups. Next, they measured the retention of automaticity at 1 day, 30 days, 90 days, and 180 days after the initial training. Overall, they found that all CM trained participants were significantly better than the VM trained participants with regard to retention. They also found that in all groups there was a significant decrement in performance at the 30-day interval and performance remained relatively stable after this initial decline.

Automaticity of Motor Tasks

Think of the task of riding a bicycle. Riding a bicycle involves the motor system in the act of pedaling to generate power, the maintenance of balance, and steering. Any motor-skill has other components, especially perceptual ones, and bicycling is no exception. Motor acts must be coordinated not only with one another but also with continually changing sensory input. Therefore, the cyclist must also perceive and respond to changes in the environment. Rapid adjustments in posture must be made in response to potholes and other variations in the road, and obstacles must be avoided. When riding a bicycle in a crowded place, such as a university campus, these adjustments must be made with precise timing and anticipation to avoid collisions. While it is beyond the scope of this paper to examine the complete processes of skill acquisition, the following sections will examine those aspects and processes of motor-skill acquisition that appear to be related to automaticity.

Overlearning

Historically, it is interesting to note that the concept of automaticity has a relationship to the classical concept of overlearning. Overlearning has been judged to be particularly important when the task is not likely to be practiced often on the job or when it is necessary to maintain performance during periods when there will be few practice opportunities. An investigation by Schendel and Hagman (1982) examined psychomotor-skills in the disassembly and assembly of weapons and demonstrated the positive benefits of overlearning. They trained soldiers to a criterion of one errorless trial and then gave 100% overtraining. Meaning, that if a participant took ten trials to perform one errorless trial of disassembly and re-assembly of the weapon, then they received 10 additional trials as part of initial training. Another group of soldiers received overtraining, but in this case each person received the particular extra trials midway through the 8-week retention period. This training was referred to as refresher training. At the end of the 8-week intervals, both the overtrained and the refresher group performed significantly better than a control group that was given just initial training. The overtrained group was superior to both the refresher group and the control group in terms of the amount retained. This is consistent with the retention findings concerning perceptual tasks. Driskell, Willis, and Cooper (1992) found in a review of over 50 studies that overlearning is an even more effective strategy for cognitive tasks than for motor tasks.

Motor-Skill Acquisition

One theory of motor-skill acquisition accounts for the improvement and increased speed of motor-skills with practice as being due to the development of schemas for the movements (Schmidt, 1975). Schmidt's (1975) schema theory takes the motor programming perspective to skill acquisition, or the idea that high-level plans guide action. According to schema theory, generalized motor programs control action. As a class of movements is practiced, the performer learns the appropriate parameter values to supply to the program and the movements become faster and more accurate. Two schemas, a recall schema and a recognition schema, are involved in this process. The recall schema serves the function of specifying in advance the initial parameter values for generating the intended movement; fast, ballistic movements are entirely controlled by these parameter specifications. The recognition schema serves as a referent against which feedback regarding performance can be compared. For slow positioning movements, mismatches between the feedback resulting from the performance of the task and that expected by the recognition schema leads to modifications of the movement as it is being executed. For both fast and slow movements, comparisons of feedback to the recognition schema enables learning to occur through the development and modification of both the recall and recognition schemas. The schema theory identifies four types of information that influence the learning of schemas when this generalized motor program is performed:

1. The environmental conditions prior to the movement.
2. Parameter values assigned to the motor program.
3. Knowledge of the correctness of the outcome.
4. Sensory consequences of the movement.

Because the learning and refinement of schemas depends on this information associated with particular instances, exposure to a number of conditions is necessary if accurate schemas are to be learned.

Neumann (1984) reviewed the research concerning three aspects of automaticity in relation to motor-skills. Neumann reviewed the traits of: being interference-free, being free from intentions, and the lack of conscious awareness. Neumann examined the data in terms of the *direction of processing theory* proposed by Shiffrin and Schneider (1977). He reviewed the notions that automatic processing occurs in a passive, bottom-up fashion, irrespective of intentions and free from interference. He compared the research findings against another view of automaticity that has developed mainly in motor research. This second view, which dates back to Wundt, regards automaticity as a matter of the *level of control*: Automatization is the acquisition of skills that enable actions or parts of actions to be controlled at a level not associated with conscious awareness. Automaticity is conceptualized as a mode of parameter identification. A procedure is automatic, if all its parameters are specified by a skill (Neumann defines this as a procedure stored in long-term memory) in conjunction with environmental information. If these two sources of constraint cannot specify all parameters, then one or more attentional mechanisms for parameter specification must come into play. These are responsible for interference and give rise to conscious awareness in motor tasks.

An action can only be performed if its parameters are specified, either in advance or during execution. This is necessary for all processes that are part of the action, both peripheral and central. The naming of an incongruent Stoop Stimulus requires, first selecting a particular aspect (the color rather than the word) of a particular perceptual object, next retrieving specific information (the color's name), and finally carrying out a certain movement sequence (e.g., pronouncing Green as quickly as possible). This could be done differently, but the action could not be carried out at all, if any of its parameters remained unspecified (Neumann, 1984). According to this *Level of control* view, the process of automatization is the acquisition of a specific skill. The availability of a specific skill, however, does not constitute a sufficient condition for automaticity. A further prerequisite is the presence of input information, which specifies those parameters not already specified by the skill. Therefore, automaticity is not an intrinsic property of processes, but an emergent property depending both on the processing system and the situational context (Neumann, 1984).

This may suggest that there are two different models of automaticity, one for perceptual tasks and another for motor tasks. Automatic components of perceptual tasks may indeed be due to a *level of processing* approach due to the fact that perceptual tasks often involve the identification of objects and this involves a level of information processing. Motor tasks, on the other hand, involve some type of behavioral performance, and automatic components of these tasks may require the parameters of the task to be specified. It would appear then, that the *level of processing* and the *level of control* are two different views of automaticity, and that the application of either model is dependent on the type of task performed.

Driving

The task of driving a vehicle appears to contain both automatic and controlled processing. Furthermore, the transformation from a novice to expert driver demonstrates the process of controlled processing changing to automatic processing. Attentional processes appear to be vital in developing automaticity of driving behaviors. For example, when someone is initially learning how to drive their attentional resources are concentrated on the basic rules (e.g., traffic light colors and meanings) and behaviors of driving (e.g., shifting gears, stopping). After extended practice these basic functions become automatized and the driver is able to make quick unconscious decisions while focusing attention to other activities such as the behavior of other drivers. Another feature of driving behavior is that it is multi-functional. For example, an experienced driver can hold a conversation or listen to the radio while driving simultaneously. The idea of multi-functional behavior is cited in Table 1 as a benefit of automatic processing. Numerous studies have examined driving and its relationship to automaticity (e.g., Michon, 1985; Rasmussen, 1987; Summala, 1988; Ranney, 1994) and will be examined in the ensuing paragraphs.

Summala (1988) examined the interaction of automatic and controlled processes in driving. He observed that novice drivers feel uncertain in most situations, but with practice, skill becomes automatized and self-confidence replaces uncertainty. When expert drivers are faced with novel or dangerous situations, uncertainty arises, which causes control to shift from automatic to controlled, conscious processing (e.g., when driving in a familiar place it is possible to be distracted with behaviors other than driving and still drive safely). However, when driving

in an unfamiliar place, or when some unordinary events occur (e.g., traffic accident) it is very difficult to perform driving behaviors as easily, thus allowing limited attentional resources for other behaviors to occur. In other words, automatic behaviors such as steering or braking are now in immediate need of attention because they have not been practiced in that particular situation extensively. This is a key finding because it gives insight into how processing changes from automatic to controlled during driving.

Rasmussen (1987) developed a hierarchy that examines the cognitive control of driving. Rasmussen described the differences between skill-based, rule-based, and knowledge-based behaviors. Skill-based behavior is the lowest level and involves automated schemata, consisting of well-learned procedures. An example would be knowledge of vehicle handling on curves. Rule-based behavior involves automated activation of rules or productions. An example would be driving an unfamiliar vehicle and understanding that the brake pedal performs the same function in the new car as it did in the previous car. Knowledge-based behavior involves conscious problem solving and is generally invoked in novel situations where no rules exist. An example would be a novice driver on first lesson having to think about when to stop or accelerate as well as what parts of the vehicle perform these tasks. Referring back to Summala's work, the process of shifting from automatic to controlled processing would be comparable to shifting from skill-based to knowledge-based processing.

Michon (1985) proposed a three-level hierarchy to underlie cognitive control of driving. The three levels include strategic, tactical or maneuvering, and operational or vehicle control. The strategic level involves general trip planning, including setting trip goals, selecting routes, and evaluating the costs and risks associated with alternative trips. The maneuvering level involves negotiation of common driving situations such as curves and intersections, gap acceptance in overtaking or entering the traffic stream, and obstacle avoidance. The operational level consists of the immediate vehicle control inputs, which are largely automatic action patterns (e.g., steering, braking, shifting). The different levels require different types of information to make decisions. For instance, strategic decisions can be largely memory-driven while maneuvering and operational decisions require immediate processing of the driving environment. Another difference concerns the time available to make decisions or think about what behavior to emit. For instance, at the operational level decisions have to be made very quickly whereas at the strategic level time is actually not a factor when making the decision.

Ranney (1994) examined various theories of driving and the role of automaticity within them. He stated that because driving involves a seemingly endless variety of situations, a model of driving behavior must allow for the development of automaticity in the absence of highly consistent stimulus conditions. Fisk and Schneider (1984) examined this idea and found that automatic processing was not limited to tasks that are consistent from input to output. By varying the consistency of attending and motor responding they found that consistent attending produced a substantial improvement in search performance regardless of the consistency of the response component. Conversely, they found that consistent responding did not affect performance. As a result of the Fisk and Schneider study, Ranney suggests that braking and steering patterns may become automatized despite differences in the characteristics of precipitating situations, such as hazards or obstacles. The concept of generalization of a learned behavior is prominent in the conclusions that Ranney reached. In summary, automatic attending

(e.g., recognition of when to stop) when driving can improve performance regardless of the actual situation in which it occurs.

Sport Related Movements

The literature examined on the training and acquisition of coordinated perceptual-motor tasks such as sports behaviors did not address the issues of automaticity per se, but it did cover some related issues such as: the requirement for specificity within the practice and the role of implicit learning in skill acquisition such as in sports related movements.

The learning of a sport related movement would be similar to that of any other simple motor task, in that learning will be facilitated to the extent that practice is consistent. That is, consistency in the practice will lead to the normal learning curves associated with practice. Buekers (2000) stated that one of the typical characteristics of an expert athlete is the ability to adapt his/her motor behavior to the requirements of the game situations. This adaptability skill, to a large part, defines an expert performer from a novice and should therefore be developed through variability in the practice conditions. Schmidt (1975) first introduced this notion, that variability is the key to developing this adaptability skill, in the *variability of practice hypothesis*. In the beginning of training sessions for general sport skills in young children, individuals are exposed to a broad variety of movements during the initial phase of sport skill learning. Later the variety of movements being trained is reduced, shifting attention from a more general approach to one in which the demands of one specific discipline (e.g., soccer, football, etc.) prevail. In these situations individuals need to execute specific game related movements. In spite of this obvious need for automatization, the high variability of the game situations requires a high degree of variability during practice. Therefore, the specific techniques have to be performed in variable situations. Taken together, it can be argued that the learning of techniques in team sports is characterized by a shift from variation in variable situations to variation in specific situations.

This method of teaching young athletes general sport skills has been generally well accepted by coaches and teachers (Buekers, 2000). This is a two-step process with the first being a developmental stage. Here the main issue is to develop an individual's capability to adapt to the changing environment. This requires an "a-specific" approach, in the sense that, from the beginning, many perception-action couplings are to be established in settings that need to maintain an "ecological relation" to the sport to be mastered at the end. The learner should be confronted with a large number of perception-action couplings that may even be a-specific to the skills to be mastered at the end of the learning process. For example, the first stage in teaching a general throwing ability in children would be to have the children throw many different types of balls; footballs, baseballs, basketballs, etc., to begin to give them a idea of how throws are made in general. This is the "variation in variable situations" from the above paragraph. The second phase of training involves the acquisition of particular skills specific to a given sport. This could be the practicing of different throws used when throwing a football; a fade route, an out, a stop-and-go, and having these performed under various game-like conditions that put constraints on the situation thereby requiring some degree of adaptability of the original motor-skill, such as: on a roll-out pass or scramble, when close to the sideline, near the end-zone, etc. Here you develop the "variations in specific situations."

Another interesting and rather new area of sport training involves the use of implicit learning strategies as a means to increase an individual's resilience to stressful experiences. It has been suggested that by reducing the amount of explicit knowledge that an individual develops in practice, the individual will be less able to "reinvest" this knowledge in times of stress. Consequently, it has been proposed that they will be less likely to regress to conscious control and suffer decrements in performance due to de-automatization (this is typically referred to as the conscious processing hypothesis). Masters (2000) reviewed work from both cognitive tasks (e.g., artificial grammar learning, sequence learning) and motor tasks (e.g., visual tracking, golf putting) that provided support for the use of implicit learning strategies. Especially in the context of perceptual-motor-skill acquisition, it is important to realize that, for the most part, learning is implicit. That is, when an individual learns a complex perceptual-motor-skill, the use and development of verbal or verbalizable knowledge is only very limited in comparison to the implicit knowledge that is being built up in the course of learning (Beek, 2000).

Masters (1992) found that experts who fail under pressure would often report that they are too aware of what they are doing, or that they have too much explicit knowledge. He argued that on such occasions the many rules that the performer has accumulated in becoming an expert will be "reinvested" in the skill, disrupting its automaticity. Masters (1992) argued that if the movement can be learned implicitly, without any explicit knowledge, then on occasions in which the performer comes under pressure this interference will be less likely to occur because the performer has no rules to reinvest. Masters (1992) investigated this hypothesis with subjects that were asked to acquire a golf putting skill either explicitly (with knowledge of how to putt) or implicitly (without knowledge of how to putt). In the explicit condition they were simply instructed, through coaching manuals, in the techniques and rules of golf putting. In the implicit condition they received no instructions and were required to carry out a highly demanding secondary task (random letter generation) throughout the practice sessions. Efficient movement patterns developed despite the fact the learners in this secondary task condition were unable to comprehend any conscious knowledge or rules about what they were doing. More importantly, when both groups were placed under stress by the introduction of an audience who evaluated their performance and a small financial incentive, the explicit learners showed a decline in their performance, whereas, the implicit learners, showed no decline, and in fact, in many cases appeared to improve.

Hardy, Mullen, and Jones (1996) replicated this finding in a research effort that furthered the methodology implemented by Masters (1992). During the stress phase of 100 trials (the learning phase consisted of 400 trials) the implicit learning group in the Masters experiment did not carry out the secondary task, so naturally they improved. Hardy et al. (1996) added a treatment condition in which subjects continued to carry out the secondary task during the stress phase. They hypothesized that this group would exhibit degradation in performance under stress equal to the group that learned explicitly. However, the performance of this implicit learning group again improved under stress, providing further support for the robustness of implicitly learned motor-skills under psychological stress.

Automaticity of Cognitive Tasks

The majority of research regarding automaticity has been with perceptual and motor tasks; the challenge is to take automaticity research into the cognitive realm. Reading contains both perceptual and cognitive components and has been examined by various researchers. Reading research, along with conditions that have historically elicited automaticity, may provide the insight needed to allow researchers to make the leap into the cognitive world.

Reading

Reading is considered a multi-functional task because perception and comprehension occur concurrently. The ability to read the text and comprehend the meaning is only accomplished through consistent practice, which leads to automaticity. Kintsch (1993) states that for skilled readers, attention and working memory resources are generally not needed for the successful execution of lower level reading components such as letter identification, word recognition, or acoustic recoding. Rather, controlled processes can be optimally allocated to text modeling (comprehension fostering) activities, including inferring the macrostructure (gist) of a passage or elaborating on the text's meaning by looking for consistencies between it and a reader's knowledge base. These issues have been examined in the psychological literature by various researchers (e.g., Fisk & Gallini, 1989; Logan, 1997; Walczyk, 2000). The following paragraphs will examine these studies and how automaticity is developed in reading.

The notion that reading requires divided attentional resources (i.e., attention divided between perceiving and understanding text) seems apparent to expert readers. Samuels and Flor (1997) indicate that automaticity allows reduced attentional demands needed to perform at a expert level during reading. Samuels and Flor suggest developing expertise occurs simultaneously when developing automaticity in reading. Thus, the development of expertise should be examined to determine what changes occur between novice and expert levels during the development of automaticity. Typically, automaticity develops with focused practice over an extended period of time, but as practice continues, there are characteristic changes in accuracy and attention. Learning can be considered both as a conscious process that changes over time, and as having phases marked by different characteristics of performance. Thus, early stages of learning tend to show performance that will be inconsistent and laborious, with many errors (characteristics of novices). Alternatively, later stages of learning will show performance that becomes faster and more accurate through the use of focused practice (characteristics of experts).

Logan (1997) examined automaticity in reading in terms of his instance theory. Instance theory, from the perspective of reading, indicates that learning can occur on a single exposure to an object or event (e.g., body of text or single word). Essentially, instance theory assumes that automatic processing is processing based on memory retrieval, and that this retrieval can happen in a single trial if a person remembers the stimulus encountered on that trial when it appears again, and responds on the basis of that memory. The idea of single-trial automatization has important implications for reading. The main requirement is that the reader encodes the relevant structures in memory (e.g., letters, words, ideas) and retrieves them when they are encountered again. The same logic can be applied to battlefield thinking. For example, if a commander is given one practice trial for a tactical strategy and encodes the scenario and thinking process that

occurred, then when this scenario is encountered on the battlefield the thinking process can be retrieved from memory with little effort.

The compensatory-encoding model, introduced by Walczyk (2000), is an innovative model that provides insights on how, when, and why automatic and controlled processes interact during various task conditions. This model incorporates pieces of reading models (e.g., verbal efficiency, meta-cognitive theory, and constructively responsive reading) along with creating new predictions about the interaction of automatic and controlled processes. The focus of the model is on advanced or expert reading levels (i.e., beyond the fourth-grade level). The compensatory-encoding model offers guidelines that will identify behaviors and strategies that will overcome deficiencies of the reader. One deficiency of reading is verbal inefficiency. Verbal efficiency is defined as the extent to which reading subcomponents (e.g., letter identification, word identification, lexical access) capable of automatization operate quickly and free of errors. Thus, if any reading subcomponents are not automatized and operate slowly with errors, then verbal inefficiency will occur. Surprisingly, verbal inefficiency and reading comprehension have been observed to be weakly correlated (Roth & Beck, 1987). This seems counterintuitive but the data show that readers who are verbally inefficient devise coping mechanisms to overcome this flaw. Still, the cost of compensatory mechanisms adds time to the overall amount of time needed for comprehension of the text. The strategies given to overcome verbal inefficiency are the slowing of the reading rate, pausing for a short time, and brief looks back over the material. Other hindrances that the compensatory-encoding model addresses are common disruptions during reading. Examples of these are encountering a low-frequency word, a contradiction in the text, or an inaccurate statement. When any of these problems are encountered the reader should refocus attention from text modeling to concentrate on the dilemma at hand, thus shifting from automatic to controlled processing. Overall, the compensatory-encoding model provides a framework of how readers are able to shift attention from automatic to controlled processing when problems or hindrances are encountered. This shift of attention is a very significant factor in the study of adaptive thinking in military leaders. Identification of the conditions that trigger the shift from automatic to controlled processes is of particular importance.

Social Judgments and Automatization of Goals: The Conditions that Elicit Automatic Processes

If one is to better determine the conditions in which an automatic process will occur in the natural environment, then one needs to be able to identify the aspects of the condition that are necessary to produce the process. That is, the preconditions that are necessary for automaticity to occur. After considering the diverse phenomenon to which the term automatic has been applied, Bargh (1992) argued that they do share one characteristic, a ballistic feature: that once initiated, these automatic processes run to completion. Bargh (1992) took this feature as a characteristic of the general class of automatic processes and argued that there are three types of conditions that "trigger" the onset of an automatic process. These conditions are similar to the production rules of Anderson (1983, 1992) and can be labeled in terms of *If (x, y, z)* → *Then (automatic process)* statements. The *x, y, z* of the *If* term correspond to the three types of eliciting conditions that may produce automatic processes and they are: preconscious, post-conscious, and goal-dependent. These three preconditions can then be used to distinguish between three types of automatic processes based on the type of condition under which they are

obtained. Preconscious automatic processes are those processes requiring only the proximal stimulus event; Post-conscious automatic processes are similar to preconscious, but also need a recent activation or "priming" event for their operation; while goal-dependent automatic processes occur only when a specific, intentional processing goal is in place.

A preconscious process is activated solely by the relevant stimulus condition; that is, it is not conditional on a particular intent, or any substantial allocation of attention, nor on conscious awareness (Speelman & Mayberry, 1998). Preconscious processes develop through considerable experience with an environmental domain and occur prior to and even in the absence of conscious awareness of the stimulus event (Bargh, 1992). Much of the work examining preconscious and post-conscious automatic process has been in the area of social cognition (e.g., formation of attitudes, opinions, stereotypes, etc.). Bargh (1992) argued that preconscious automaticity is the most prevalent type of automatic processing in the natural environment, because all that is needed for the automatic process to occur is the initiating stimulus event. Shiffrin and Schneider (1977), among others, demonstrated that frequency and consistency of processing a stimulus event in the past is a prerequisite for the development of an automatic process. Therefore, the "relevant stimulus event" is likely to be present often, and so the preconscious analysis of this event is likely to occur often (Bargh, 1992).

The prototypic example of post-conscious automaticity is in priming effects, which have been widely studied in social judgment research. In these studies, a word with some social or affective labeling value such as *intelligent* or *aggressive* is activated by relevant stimuli in one task (such as unscrambling word sequences to form a grammatically correct sentence). It is found that these subjects, in what they believe to be an unrelated task on impression formation, are more likely than unprimed subjects to interpret an ambiguously trait-relevant behavior of a target person in line with the primed construct. The primed constructs, while they remain active in memory, display what appears to be a preconscious effect on the interpretation of an ambiguous stimuli (Bargh, 1992). Therefore it would seem that post-conscious and preconscious automaticity are equivalent effects, with the only difference being the necessity of priming or the pre-activation of the relevant construct.

While preconscious processes may be the archetypal automatic process, it does not appear to be the most relevant to the acquisition or development of skilled performance. In most examples of skilled performance there must be some intention to engage in an activity (e.g., driving) if an automatic process (e.g., braking at a red light) is to be observed. Therefore, the performance of some automatic processes may also require a specific processing goal to be in place. Procedural knowledge structures that have become automatic with practice or frequent use are the best example (Anderson, 1983, 1992). What goal-dependent processes require is the guidance of the processing goal by some intent, plus the presence of the relevant triggering stimulus (Bargh, 1992).

Bargh and Ferguson (2000) talked of how environmental cues may trigger the pursuit of goals. The mental representations of goals may develop automatic associations to other representations that are frequently and consistently active at the same time (Shiffrin & Schneider, 1977; Shiffrin & Dumais, 1981). That is, if a person consistently chooses to pursue the same goal within a given situation, over time that goal structure becomes strongly paired with the

features of that situation. After this consistent pairing of the situation with the intended goal, eventually, the goal itself is activated on the perception of features of the situation in a preconscious analysis. Bargh and Ferguson (2000) stated that this is an unintentional form of skill acquisition, because just as with desired skills (driving, reading, etc.), in which a person wants to automate the components of the skill to better perform it, goal pursuits can become automated through the same practice of that goal through frequently and consistently pursuing it in that situation. Therefore, automatic processes may be initiated by controlled or automatic goal-directed behavior.

The Development of Automaticity

While Shiffrin and Schneider (1977) may have characterized the differences between automatic and controlled processes, they did not describe the mechanism whereby controlled processes can become automatic. Shiffrin and Schneider (1977) discussed the importance that practice has in shifting processes from controlled to automatic and the types of practice that are necessary for this to occur, but they did not discuss how practice leads to the characteristics of automaticity identified earlier. Recent theories of skill acquisition have identified two ways in which controlled processes become automatic: Procedural accounts and Memory accounts. The procedural account states that procedures for performing tasks are refined and strengthened with practice, while the memory account states that performance is determined by memory retrieval, and this process becomes faster and more efficient with practice (Speelman & Mayberry, 1998). Besides these procedural and memory accounts for the acquisition of automaticity, a number of other areas relevant to skill development will be examined.

*Procedural Accounts: Anderson's ACT**

Fitts (1964) stated that there are three phases involved in the acquisition of skill. The first stage was called the cognitive stage. This stage lasted only a few trials while subjects come to terms with instructions and develop performance strategies. These strategies develop from general "sets" and strategies developed from previously learned tasks (Fitts, 1964). Knowledge here is explicit and typically rule-based, and performance is slow and error-prone. This stage involves strong demands on cognitive-attentional resources. Refinement of the performance strategy comes in the intermediate phase - the associative stage. Features of the previously learned strategies that are appropriate to the new situation are strengthened on the basis of feedback, whereas inappropriate features are weakened. This process forms new association between specific stimulus cues and appropriate responses. In the end phase - the autonomous stage- the components of the performance strategy slowly become more autonomous so that they are less subject to cognitive control or external interference. As a result, skilled performance of the task requires increasingly less processing, which means that more processing resources can be used for other activities. During this phase, skills continue to become faster and more efficient although the rate of improvement slows considerably.

Shiffrin and Schneider's (1977) framework of controlled and automatic processing features these three stages of skill acquisition. The qualitative differences in performance associated with the three phases are said to result from a gradual shift from controlled to automatic processing. Performance in the first phase is attributed to controlled processing.

Performance in the second phase involves a mixture of controlled and automatic processing, and the third phase is associated mainly with automatic processing (Speelman & Mayberry, 1998).

Fitts (1964) did not however, provide a clear process description of how performance strategies are refined though the various stages of skill development. A description of the processes involved in skill acquisition is necessary to be able to understand how automaticity might result. A comprehensive account of skill acquisition is provided by Anderson's ACT*, and later his ACT-R theory, (1982, 1983, 1987). The ACT* model accounts for Fitt's (1964) three phases of skill acquisition and details the processes within each to a greater extent. According to ACT*, the cognitive phase involves the acquisition of explicit knowledge. Knowledge of this type is typically in the form of declarative rules concerning a particular domain. For example, an inexperienced officer in the field may remember being told by an experienced superior to be mindful of a particular type of terrain. The memory of this advice is declarative knowledge. The *associative* phrase skill acquisition involves the compilation of declarative knowledge into procedural knowledge. This is described as the acquisition of production rules: rules that associate particular stimulus conditions with appropriate actions (i.e., *If- Then* rules, *If* encounter this type of terrain- *Then* consider this type of action). Acquisition of this type of knowledge corresponds to a dropout of the verbal rehearsal of instructions and the associated reduction of working-memory load, resulting in smooth and accurate performance. The autonomous phase of skill acquisition involves a strengthening process that enables fast, reliable execution of productions. Performance at this stage of practice usually proceeds without thought, and may appear automatic, given sufficient practice (Anderson, 1982, 1983).

According to ACT*, there are two ways in which skill acquisition can result in automatic performance: compilation and strengthening. The first way is through the compilation of declarative knowledge into procedural knowledge. Compilation is made up of two other processes: proceduralization and composition. Proceduralization refers to the process whereby declarative knowledge is converted into productions. This process leads to knowledge that is in a form that is difficult to describe verbally. Anderson (1982) stated that productions cannot be reported verbally because they do not alter the contents of working memory. In ACT* only the contents of working memory can be reported, not the processes that led up to these contents. If someone was asked to report on their procedural knowledge, at best they could only describe the successive contents of their working memory, and therefore reconstruct what must have taken place during performance.

The other process involved in compilation is composition. Composition describes the process whereby several productions are collapsed into a single production. These productions must occur in a sequence and share the same overall goal. The new production now does the work of the sequence, but in fewer steps and thereby in less time. The following is an example by Speelman and Mayberry (1998) of the compilation of a sequence of productions.

Solve for x in the expression $a = x + c$

1	IF	Goal is to solve for x in the equation $a = x + c$
	THEN	Set as subgoal to isolate x on right-hand-side of equation

2	IF	Goal is to isolate x on RHS of equation
	THEN	Set as subgoal to eliminate c from right-hand-side of equation
3	IF	Goal is to eliminate c from right-hand-side of equation
	THEN	Subtract *c* from both sides of equation
4	IF	Goal is to solve for x in the equation and x has been isolated on the right-hand-side of equation
	THEN	Left-hand-side of equation is solution for x

After executing these rules a number of times, composition will result in collapsing productions 2 and 3 into:

5	IF	Goal is to isolate x on right-hand-side of equation
	THEN	Subtract *c* to both sides of equation

With further practice, productions 1,5, and 4 will be composed to the more sophisticated:

6	IF	Goal is to solve for x in equation of the form a = x + c
	THEN	Subtract c from a and result is solution

Due to this reduction in the number of steps needed to perform the task, the contents of working memory are not updated as often throughout the task and therefore, cannot act as clues to how the task was performed. This could account for some experts' inability to verbally describe the use of their expert strategies. Only the initial conditions and the final product of performance appear in working memory, and so only these are available to report (Speelman & Mayberry, 1998).

In addition to the increased efficiency in performance, compilation also leads to a speed-up in performance. Compiled productions perform tasks in fewer steps and if each step is associated with a unit of time, then this translates into less time for performance. However, compilation alone is not enough to account for the vast amounts of time decreases that accompany skill acquisition. This is where the second characteristic of skill acquisition- *strengthening* - comes into play. The strength of a production determines how rapidly it applies, and production rules accumulate strength, as they are successfully performed. That is, if a production has had *X* exposures, then it has a strength of *X*. Each time a production rule or declarative fact is used it is increased in strength by one increment, and one can approximately say that a production is automatic to the degree that it is strong (Anderson, 1992).

Anderson (1982, 1983, 1992) states that the combination of the processes of *compilation* and *strengthening* account for the classic power functions that characterize learning curves. Anderson (1992) also claims that the ACT* theory can account for most of the commonly described features of automaticity. His research used the ACT* theory to account for the more common features of automaticity associated with the visual search tasks in such as in the work of Shiffrin and Schneider (1977). Anderson (1992) used ACT* theory to explain the effects of CM and VM practice. In the visual search paradigm participants are required to recognize a digit

when it appears on the screen, and to set a subgoal of classifying the digit and say the appropriate response. Anderson (1992) proposed that in the initial stages of practice, subjects would develop productions similar to the following in order to perform the task:

1	IF	The goal is to categorize a stimulus in location X and n1 is in location X
	THEN	Set as subgoal to determine the category of n1 and say the category name of n1 (target, distracter)
2	IF	The goal is to determine the category of n1 And n1 is in set Y
	THEN	n1 is in category Y
3	IF	The goal is to say the category name of n1 and n1 is in category Y and R is the response for Y
	THEN	Say R

However, with practice, Anderson claimed that subjects eventually would develop productions of the form:

4	IF	The goal is to categorize a stimulus on the screen and a target stimulus is on the screen
	THEN	Say yes

Compilation occurs and combines productions 1,2,3 into 4. With further practice, production 4 will be strengthened and this will facilitate its faster performance. Other productions will be developed that are specific to other elements of the target set. Eventually, specific productions are developed to classify each item in the target set. Regardless of the size of the target set, with sufficient practice, there will be a specific production rule for each item in the set. This leads to the disappearance of set size effects after practice, because each item in the target set is classified by a compiled and strengthened production. This accounts for the lack of set size effects in CM, because CM enables the development of a production for each item in a target set.

The difference with VM practice is that the items in the target set vary from trial to trial. This does not allow the development of specific production rules for each item. Participants have to rely on more general productions, such as:

5	IF	The goal is to categorize a stimulus on the screen and n1 is on the screen and n1 is in the target set
	THEN	Say yes

This production is more complicated than production 4 and will be performed more slowly. Also, because production 5 requires verifying whether a number is in the target set (i.e.,

n1 is in target set) the time to match this condition will be affected by the size of the target set. VM practice offers little opportunity for learning and should show set size effects due to this lack of consistency in the target set and thereby, not allowing the development of item specific productions (Anderson, 1992).

Anderson (1987) provided an example of the transition from declarative to procedural knowledge in which the problem-solving behavior of an individual who was learning to write functions in the programming language LISP was evaluated. After receiving some preliminary instruction in LISP, which included description of some of the basic functions of the language, the novice programmer was presented with the task of writing a function called FIRST that would return the first item of a list. FIRST had the same purpose as the system function CAR to which the participant had already been introduced. Therefore, the task was just an exercise in the syntax of function definition. To start the problem-solving process, five pages of text were provided that described how to define functions using the LISP function DEFUN. Included in the text was an abstract template showing the parts of the function definition and some sample definitions. This information provided the declarative knowledge needed for the task. After completing the task of writing the FIRST function, a second, similar task, of writing another function called SECOND was administered. Anderson (1987) found that the second task was performed much more quickly and requiring a fewer number of steps. Anderson (1987) stated that the lengthy declarative knowledge used in the first problem was compiled and thereby reduced and sped-up for use in the second task.

An example of the effects of practice on proceduralization is Neves and Anderson (1981). They had individuals solve geometry-like proofs developed from an artificial postulate set. Proofs were displayed by computer on a terminal screen, however only part of the proof was visible at any time. The subject had to explicitly call for the part of the proof that was to be looked at next. They did this in order to evaluate what the individuals looked at and measure how long they looked. The screen had labeled columns for givens, statements, reasons, and antecedents and consequent of the postulates. At all times the statement to be justified was displayed on the screen. The subject pressed keys to view anything else. They found that performance improved across trials, with total time, total number of steps, and time per step all following the typical power functions associated with learning.

In summary, Anderson's ACT* theory suggests that many of the features of automaticity result from the compilation of declarative knowledge into procedural knowledge. With practice, this compilation leads to very efficient and fast productions that are not accessible to verbal description. This would imply that much of the implicit nature of some forms of expertise might result from the automatic application of knowledge that was previously explicit.

Memory Accounts

An alternative view proposes that many features of automaticity result from the effects of practice. The instance theory is an alternative method of understanding automaticity and attention in comparison to procedural accounts such as ACT*. The instance theory asserts that automatic performance is based on the retrieval of past solutions from memory (Logan, 1988). For example, the more times a phone number is dialed (retrieval of past solution), the more

automatic it will become. In terms of thinking processes, the more chances an individual has to think about a situation the more automatic that thought process becomes. The instance theory consists of three main assumptions. First there is obligatory encoding of material to which one attends. The obligatory encoding assumption provides the learning mechanism. In other words, attention to objects and events in the course of performing a task causes a task-relevant knowledge base to be built. Next, there is obligatory retrieval of instances that are associated in memory with the material to which the individual is attending. The obligatory retrieval assumption is responsible for the expression of automaticity in performance. The more an individual responds to an object the stronger the link is between that response and object. Finally, memory representations are instance representations meaning that each instance is a separate representation that causes performance to become automatic. Based on these assumptions, automaticity is developed through the acquisition of instances stored in their memory. The more practice the person has with the task creates more instances of the task in memory, thus developing automaticity. In summary, instance theory implies that automaticity is developed through specific instances that create strong links between the stimulus and response to that situation.

Boronat and Logan (1997) examined the relationship between automaticity and attention with regard to the instance theory. The experiment investigated whether attention selects the material to be encoded, the material to be retrieved at test, or whether it performs both functions. The results indicated that the participants achieved some level of automaticity. First, the difference between experimental conditions decreased with practice. Secondly, participants became faster across training blocks. These findings support the belief that consistent practice develops automatic processing (i.e., more practice equals more instances).

Another account of expert performance relates many of the automatic features of expertise to highly efficient memory retrieval processes. Unlike Logan's theory, which describes automaticity as resulting from the retrieval of memory instances from an ever-increasing distribution of instances, skilled memory theory (Chase & Ericsson, 1982; Ericsson & Staszewski, 1989; Staszewski, 1988) claims that many of the features of automaticity result from a highly specialized long-term memory store paired with extremely efficient retrieval mechanisms (Speelman & Mayberry, 1998). While instance theory views expert performance as almost a by-product of the representation of a large amount of information in memory, skilled memory theory depicts expert performance as related to changes in the way information is represented in and retrieved from long-term memory. Skilled memory theory is not thought to be a comprehensive theory of skill acquisition; however, it does account for some of the automatic features of expert performance.

The skilled memory theory (Chase & Ericsson, 1982) proposes that experts develop exceptional memory abilities with practice and that these can be characterized by three principles. The first principle is referred to as the *meaningful encoding* principle. This depicts the way in which experts process information in their domain of specialization and the memory benefits this brings. The principle states that experts use their extensive prior knowledge to process information about familiar tasks in meaningful ways. This then leads to more elaborate and accessible memory representations than those formed by novices. Experts' specialized knowledge enables the organization of information into meaningful chunks that are

automatically accessed and retrieved (Speelman & Mayberry, 1998). This chunking ability enables experts to bypass the usual capacity limitation of short-term memory (i.e., 7 $\pm$ 2 items). Evidence for this meaningful encoding principle comes from the research of chess masters (deGroot, 1966, 1978; Chase & Simon, 1973) and the above research by Chase and Ericsson (1982).

In Chase and Ericsson's (1982) study two people practiced a digit span task for two years. The basic procedure involved listening to a sequence of digits spoken at a rate of one per second and then recalling the digits in the same order. If all digits were recalled correctly, the length of the next list was increased by one digit, and if they were not all recalled correctly, the length was decreased by a digit. The original participant, SF, had a memory span of seven digits for the lists presented during the first 4 hours of the experiment. The participant's digit span remained under 10 digits throughout the first 4 days of practice and then on the fifth day suddenly increased to more than 10 digits. This increase could be attributed to the development by SF of a new mnemonic strategy. The participant was a long distance runner, and he used his knowledge of running times as a mnemonic aid. For example, the sequence of 4003911 would be remembered as 4 minutes 39 seconds and 11/100th of a second. From the fifth day of the experiment onward, he expanded this scheme of encoding digit groups in terms of running times and also added other categories, such as years and ages, for digit groups that could not be encoded as running times. His performance continued to improve across 2 years of practice, reaching 82 digits by the time the experiment stopped.

The second principle of skilled memory theory is the *retrieval structure* principle. According to this principle, experts make use of memory structures to keep track of serial order and/or the intermediate results of processing. The nature of these memory structures reflects the experts' awareness of the types of constraints present in frequently encountered problems. The advantage of retrieval structures is that, when processing familiar material, experts can access and utilize their extensive knowledge and keep track of important information. For example, Ericsson and Staszewski (1989) found in their work with expert mental calculators (individuals trained to work mathematical problems such as 24 x 23,345 without calculators, pencils, or paper) that these individuals make use of organized data structures that enable efficient encoding, representation, and retrieval of digit strings during computation. These structures help overcome the memory load associated with remembering multiplicands and intermediate results. Other types of experts use other types of structures that reflect different purposes (Speelman & Mayberry, 1998).

The third principle of skilled memory is the *speed-up* principle. This principle states that practice will result in the increased speed of retrieval from the long-term memory until it eventually reaches the speed in which information is accessed in the short-term memory. Evidence that retrieval times are reduced in the long-term memory has been reported with mental calculators (Ericsson & Staszewski, 1989), and chess players (Staszewski, 1988).

In summary, skilled memory theory accounts for the exceptional memory skills of some experts by proposing that experts use their extensive knowledge to process information in terms of meaningful chunks. This enables experts to encode, process, and retain a greater amount of information than would normally be possible within the limits of the short-term memory.

Experts also use retrieval structures that organize the information being encoded and processed. These structures facilitate the retention of information that is important for efficient performance, such as serial order. Finally, experts have practiced the retrieval of specific types of information from the long-term memory to the extent that it is as fast as retrieving information from short-term memory. Together these three principles lead to memory performance that has the characteristics of the short-term memory with an expanded capacity, but in fact is the result of a highly efficient long-term memory (Speelman & Mayberry, 1998).

Skilled memory can be used to explain a number of the characteristics of automaticity. First, much of the rapid performance of many experts can be attributed to highly efficient retrieval from a long-term memory full of domain-specific knowledge. For example, chess masters can encode a board full of pieces in 5 seconds (Chase & Simon, 1973). Their chunking ability enables them to recode a large amount of information into a smaller set, and their extensive practice has meant this process is fast. Therefore, the master can look at mid-game configurations and immediately "see" meaningful configurations among the pieces, the same as normal readers can look at a page of letters and see words.

A second feature of automaticity, although less strongly accounted for by skilled memory, is its implicit nature, or the lack of awareness about the ongoing process. Chess masters appear to encode familiar information in long-term memory incidentally while they perform particular tasks. When chess masters are asked to suggest the next move from a configuration of pieces, they recall as much information about the configuration in a surprise recall as when they are warned of the recall in advance (Lane & Robertson, 1979). The ability of mental calculators to recognize old problems from new ones with 80% accuracy (Staszewski, 1988) has also been used to demonstrate this incidental encoding feature of automaticity. These results may suggest that when an expert encounters familiar material a trace is automatically processed and left in the long-term memory.

A third feature of automaticity that may be attributed to skilled memory is the resistance to capacity competition, or the ability to multi-task when automaticity has occurred. Experts in many domains exhibit resistance to working-memory capacity constraints. Experts have the ability to execute tasks that apparently involve a heavy memory load with ease. According to skilled memory theory, this is because experts' memory for familiar material is so fast and efficient that there is little competition for cognitive resources with other forms of cognitive processing (Speelman & Mayberry, 1998). Staszewski's (1988) research of two mental calculators involved two forms of problem presentation: oral and visual. The oral condition involved a heavier memory load due to the calculators needing to remember both the numbers and the intermediate results during the calculations. The oral presentation of the problems demonstrated this heavier load via longer solution times verses the visual presentation of the problems. However, with extensive practice, the differences in solution times between the oral and visual conditions disappeared. This demonstrated the ability of the mental calculators to develop memory skills that alleviated the additional load imposed by oral presentation of the mathematical problems. This is thought to display that some of the resistance to capacity competition in automatic performance may be attributed to skilled memory (Speelman & Mayberry, 1998).

Knowledge Representations

The skilled memory theory is closely linked to the idea of the mental models of experts. A mental model can be thought of as a representation of a body of knowledge and the interconnections of its components. There have been many cognitive structures proposed to explain how people represent knowledge and reason with it, including: schemata (Bartlett, 1932), semantic networks (Quillian, 1968), frames (Minsky, 1975), and scripts (Schank & Abelson, 1977). Many of these could be used interchangeably within the skilled memory theory. The key is that the representation of the world is dynamic, and the individual uses the representation to understand the world around them and predict possible future states (Rouse & Morris, 1986).

Scripts were chosen for the context of this paper because it was felt that an individual's cognitive script was the most relevant in the context of battlefield situations. A script provides the consistent structure that is needed for the stereotyped actions and battle-drills of battle command, while also allowing for the uniqueness or variability within the situation. The term "script" was originally used by Schank and Abelson (1977) to refer to the stereotypical knowledge structures that people have acquired about common routines, such as going to a restaurant, visiting a doctor, etc. Scripts are a part of the more general *event schemas*, which are hierarchically organized sets of units describing generalized knowledge about a sequence of events (Mandler, 1984). A script is a generic knowledge structure concerning some particular type of event (e.g., restaurants dining, doctor visits), and tied to the content within that event. It includes knowledge about what will happen in a given situation and often the order in which individual events will take place. It is organized much like a categorical structure in that the knowledge is arranged in a hierarchy with more general classes of events containing more specific events nested within them. Schematic script hierarchies consist of part-whole relations, and not class inclusion relationships, meaning, that while *dog* is a type of mammal, sitting down at a table is not a type of restaurant dining, it is a part of restaurant dining. A script is a structure that describes appropriate sequences of events in a particular context. A script is made of slots and requirements about what can fill those slots. The structure is an interconnected whole, and what is in one slot affects what can be in another.

Scripts of situations are thought to develop through the repeated exposure to the situation (Fiske, 1995; Mandler, 1984; Schank & Abelson, 1977). This is based on the position that memory is episodic rather than hierarchical and that not only is information stored in episode form, but that it is acquired in that way. An individual learns about the order of processes in a restaurant by experiencing the situation enough times. This is similar in any situation, that is, only through experiencing the situation a number of times, does the individual begin to see the similarity among the experiences. This could be seen as being similar to the requirement of consistency within the practice sessions observed in the development of automaticity (Shiffrin & Schneider, 1977). Initial exposure to a situation leads to the development of an initial determination of how the situation occurs. This consists of the initial definitions of the objects as a part of the episode in memory. After a number of exposures to the situation, a rigid protocol (based on the limited number of episodes experienced) or script is formed to connect the episodes. As more and more exposures to the situation occur, then the additional information from these exposures is incorporated into the script. Finally, the scripts are organized by an

overall goal structure that is used to make sense of the numerous episodes linked by the script (Schank & Abelson, 1977).

Schank and Abelson (1977) stated that individuals use specific knowledge to interpret and participate in events that they have been through many times. Specific detailed knowledge about a situation allows us to do less processing and wondering about frequently experienced events. Schank and Abelson (1977) characterized scripts as containing a number of scenes, for example, in the restaurant script there are scenes for entering, ordering, eating, and paying. They also stated that within each of these scenes there are a number of action variables that may occur. The entering scene consists of the customer entering the restaurant, looking for a table, deciding where to sit, going to the table, and sitting down. Ordering consists of getting a menu, looking at it, deciding what to eat, and giving the order to a waiter or waitress. Also, associated with these actions are typical roles, such as the waiter and the customer, and typical props, such as tables, chairs, menus, etc. (Mandler, 1984). Thus, the restaurant script must contain a tremendous amount of information that encompasses the enormous variability of what can occur in a restaurant. There must also be a *fast food* script, an *expensive restaurant* script, etc., that include the entering, ordering, and paying scenes, but have a different set of possibilities than the ordinary restaurant script. In the *fast food* script, paying can occur immediately after ordering and before eating; eating may occur inside or outside the restaurant; the person who takes the order must be approached by the patron rather than going to where the patron is seated (Schank & Abelson, 1977).

Bower, Black, and Turner (1979) suggested that the scenes in scripts represent actions organized around the sub-goals involved in achieving the main goal of a script. In a restaurant script the main goal of eating can be broken down into a series of sub-goals, such as getting into the restaurant (the entering scene), ordering the food, eating the food, paying the bill, and leaving. However, multiple scripts may be co-occurring at any time. Within any situation, there may be several scripts that are being applied to the situation. Within a restaurant script there may also be a *first date, or important business meeting* script, each of these with their own goal hierarchy that would make simply assessing the goal hierarchy of the restaurant script alone not sufficient in accounting for the behaviors and information processing that occurs.

Most of the research concerning schemas deals with identifying their components in situations, looking across individuals to determine the scripts content, or looking at how scripts can bias and influence decision-making in social situations. The wealth of research on schemas, and script schemas in particular, deals with those issues; the development of the scripts is viewed as the result of numerous exposures to situations. While Schank and Abelson (1977), based on their early research, do suggest a process of script formation (episodes lead to scripts that lead to a goal hierarchy), no attempt was found in the literature to formulate a training methodology based on that process. Nonetheless, since the formation of scripts is clearly related to the building of expertise, an instructional program designed for training scripts could be developed, along with a methodology for assessing the complexity of the scripts. The complexity and structure of the scripts may serve as an indication of the level of expertise an individual possesses. The greater the complexity (the greater the number of variable actions, or possibilities contained within the script) of an individual's script, the greater is the knowledge of a situation and therefore, the greater the level of expertise.

Training Automaticity

Within the last 15 years the importance of an approach to training that capitalizes on automatization or overlearning has been reported in recent reviews of the training literature (Goldstein, 1986, 1993; Howell & Cooke, 1989). Goldstein (1986) discussed the criticality of overlearning (which may be analogous to automatization) for situations in which the task will not receive a lot of practice in the work setting in order to maintain performance levels under stress, over time, and to ensure asymptotic performance on all criteria. More recently, Goldstein (1993) described automaticity as a "crucial point in instructional theory" (p.110). Howell and Cooke (1989) discussed the importance of automaticity to free up attentional resources for the more complex tasks. These authors all emphasized the importance of automaticity for training. However, they do not provide a means by which to implement the theory of automatic processing to training.

Within any complex task the multiple processing demands of the task components are usually the most difficult aspect of performance. Therefore, identifying the automatic components of a complex task and then training those to levels of automaticity will enable cognitive resources to be devoted to the more strategic, controlled components of the task. Schneider, Vidulich, and Yeh (1982) developed and initially validated a training program for air traffic controllers that was based on the desirability of developing automatic task components. Listed below are the 10 rules Schneider et al. (1982) used to develop the training program:

1. Present information to promote consistent processing by the operator.
2. Design tasks to allow many trials of critical skills.
3. Do not overload working memory and minimize memory decay.
4. Vary those aspects of the task that vary in the actual situation.
5. Minimize passive observation and maximize active participation.
6. Maintain high motivation.
7. Present information in a context that illustrates the criterion task without information overload.
8. Train under mild speed stress.
9. Train operators to use strategies that minimize workloads.
10. Test operators under high-workload conditions to assess competence and facilitate automatic process development.

The training program consisted of 10 training stages made up of a mixture of part training and transfer conditions. Such specialized skills as estimating the distance between aircraft and identifying the starts of turns were taught in discrete stages, and performance on the component tasks was measured under high workload conditions in which a secondary task was also being performed. The initial results of the program suggested that perceptual learning of the type required for air traffic control could be accelerated when component skills are learned in a consistent environment.

Controlled and Automatic Processing Task Analytic Methodology

It has been hypothesized that the thought process contains many elements, some of which can become automatic while others cannot. Rogers, Maurer, Salas, and Fisk (1997) have conducted extensive research to understand the boundaries and intricacies of skill development in automatic process development. The results of that research suggest that there are specific principles involved with developing automatic processes. Nine principles form the basis for the Controlled and Automatic Processing Task Analytic Methodology (CAPTAM).

Principle 1

Performance improvements will occur in situations where stimuli are responded to in a consistent manner across exposures. Consistent mapping, developed by Shiffrin and Schneider (1977), is an example using letter and numbers as stimuli. Performance was improved using consistent spatial stimuli across situations as well (Ackerman, 1986; Eberts & Schneider, 1986).

Principle 2

Consistent relationships at abstract or higher-order levels and consistent rules should be identified. In many real-world tasks, the stimulus-to-response consistency may be at a higher level that is not immediately obvious. Patterns of information or rules may be consistent, but individual stimulus items may vary across situations. For example, in football what differentiates a player as the appropriate receiver is a function of the dynamics of the situation (Walker & Fisk, 1995).

Principle 3

The degree of performance improvement is directly related to the degree of consistency. In the real world, it is impractical to think that situation and task demands will be completely consistent. Schneider and Fisk (1982a) demonstrated that conditions that were at least 67% consistent yielded significant performance improvements, and that performance was more indicative of automatic processing than of controlled processing.

Principle 4

Contextual cues should be used to mimic the effects of consistency and may activate automatic sequences of behavior. Fisk and Rogers (1988) and Rogers, Lee, and Fisk, (1995) demonstrated that subjects could benefit from contextually defined consistency, such that performance was superior to VM performance. For example, the functions associated with particular keys across word-processing systems are context-dependent. The F1 key may save the document on a Windows operating system, but may serve another function on a UNIX operating system.

Principle 5

Long-term retention differs across task components (automatically processed components vs. controlled components). Fisk and Hodge (1992) measured retention at intervals up to 1 year after practice, and found that the performance characteristics of automatic processes were well maintained even after long periods of disuse. Interestingly, Fisk, Hertzog, Lee, Rogers, and Anderson (1994) found that across experiments there was a decline in search conditions that required information coordination. These findings indicate that although the automatic processes may not have decayed, the strategic, controlled processing aspects of the task did.

Principle 6

Consistent task components must be identified and trained to levels of automaticity to minimize mental workload. Automatic processes have been shown to be less consumptive of attentional resources. Thus, the more task components that can be automatized, the less mental workload there will be with regard to attentional resources (Schneider & Fisk, 1982b).

Principle 7

Training to levels of automaticity will also make performance reliable under environmental stressors such as alcohol, fatigue, heat, noise, and so on. Several studies indicate that consistent task training can make performance resistant to the effects of heat stress, alcohol intoxication, and fatigue (Fisk & Schneider, 1981, 1982; Hancock, 1984, 1986).

Principle 8

Pretraining of task components to automaticity may be beneficial for complex tasks. A number of studies have been conducted to examine if pretraining and part-task training techniques are beneficial for automatizing task components (e.g., Eggemeier, Fisk, Robbins, & Lawless, 1988; Fisk & Eboch, 1989). The results suggest that pretraining of task components that can be recombined for the whole task is effective.

Principle 9

Part-task training may also be beneficial for complex tasks. Part-task training may be especially useful for tasks that are initially too difficult for novices to perform (Wightman & Lintern, 1985).

The relatively broad-based applicability of the principles of automatic processing serves as the foundation for CAPTAM. The challenge of a training program for battlefield thinking is to determine where the consistencies lie. In other words, are the consistencies simple stimulus-response consistencies, higher-order consistencies, or even less than perfect consistencies? The following section will examine CAPTAM in greater detail.

The general goal of CAPTAM is to identify task consistencies that can be trained. Task consistencies may not be immediately obvious. Researchers should be aware of this fact and

should look for higher-order or rule-based consistencies. The CAPTAM technique utilizes the procedure of job or task analysis to specify fundamental issues of the job to determine what needs to be trained. There are four fundamental issues that have to be addressed prior to the implementation of the CAPTAM methodology.

The first fundamental issue is determining from whom the job data will be obtained. Many researchers feel that it is important to gather data from various levels of job experience. Therefore data collection on battlefield thinking should include officers at several echelons and with varying ranges of experience. The second issue involves the methods of obtaining data (e.g., observation, interview). If a research effort is developed from this report the observation of commanders solving military problems during simulations or live exercises and an ensuing interview concerning their thinking would be optimal. The third issue concerns the type of job descriptor. The researcher must decide whether the focus is on the tasks and activities performed, the physical demands, working conditions, abilities and skills, and so forth. In CAPTAM, the foci are education and training required to perform the tasks, the degree to which task components may be automatized, and the differences in task performance under various conditions of stress and overload. The factors that CAPTAM emphasizes would be ideal for a training program to automatize components of the thinking process. The last issue is to determine the purpose of the analysis or study and how the results be utilized. Once these are determined, the training program can be developed.

There are three comparisons of expert/novice differences that are useful to examine in using CAPTAM implementations. The researcher must determine what difficulties are evident for novices but not for experts. Those task components or decision points would likely be amenable to consistent training for automaticity. Next, it must be established where the performance of novices breaks down under conditions of stress, time pressure, or fatigue but remains constant for experts. Not only is it an issue of extreme importance on the battlefield, according to Principle 7, it indicates behaviors that are likely automatized in experts. The final issue associated with expert/novice differences is determining the task components or decision points for which experts report high workload. Doing this will allow the trainer to decide which task components or decision points need to be part-task trained, thus providing experts and novices the opportunity to learn and transfer these tasks to the job while reducing cognitive overload (Wightman & Lintern, 1985).

Anderson (1982) made a distinction between declarative knowledge, which is fact knowledge (knowing what), and procedural knowledge, which is knowledge of procedures (knowing how). To develop an effective training program several points must be addressed regarding declarative and procedural knowledge. First, the researcher must determine what information is necessary to perform the task. Focus on the kind of background knowledge the commander must have for the task (or task component). The trainer should also determine aspects of the task that are easy for the expert to write down or verbalize. Consistent task components identified during this procedure can be trained, such that eliciting stimuli will automatically evoke associated declarative knowledge. Next, the trainer must determine the steps involved in performing the task. Anderson (1982) states that consistent training of the more procedural components can result in the compilation and proceduralization of the process, such that component steps are combined and one stage leads directly to the next. In some cases,

consistent practice can lead to direct memory access, such that the execution of the recipe or algorithm is no longer needed (Logan, 1988). During this stage a comparison of expert and novice descriptions of the steps involved in a task is critical because experts may not be able to describe each step of the process due to automatization or proceduralization.

The next step of the task analysis for CAPTAM is the identification of consistencies. Several types of consistencies are vital to the development of an effective training program. The training developer must first identify local level consistencies such as basic stimulus-response associations. Local level consistencies are defined as being a response made every time a stimulus is presented. This may be difficult because of the complexity and dynamic nature of battlefield thinking. Next, the trainer must identify what consistent categories of information exist. The next type of consistencies to be identified is what consistent rules exist. An example of consistent rules in a commander's thinking would be to maximize all assets in any situation. Next, the researcher should identify context-specific consistencies. Rogers, Maurer, Salas, and Fisk (1997) state that training contextually relevant responses is particularly important for military personnel. These individuals must learn to differentiate friend or foe before shooting, and those decisions are contextually determined. Another example of context specificity is determining which tactical maneuvers to execute during the battle. Finally, the trainer must identify where and how task goals consistently change performance. The best approach in CAPTAM is to observe the responses made to stimuli under different goal conditions.

The next phase of CAPTAM is the collection of data pertaining to the task to be trained. One approach that had been successfully applied involves semi-structured interviews of individuals within the job (Eggemeier et al., 1988). Ideally, the interview team will consist of one to two individuals who are familiar with the basic principles of controlled and automatic processing theory. This basic knowledge is necessary to allow the interviewers the ability to ask the appropriate questions and to interpret the answers. Another member of the interview team should be a subject matter expert (SME) in the topic area. That person should have extensive knowledge of the task (e.g., experienced officer) and will provide assistance to the other interviewers to ensure the entire domain of the task is examined. Leaders with varying levels of expertise and experience should be interviewed to ensure that as much information as possible concerning the task is acquired. Differences and similarities in the answers will provide pertinent information concerning consistent task components and will guide other training decisions. The choice of a group versus individual interview can be made by the interview team and will be influenced by many factors (e.g., time, rank of individuals). Experts provide insights into the final outcome once the components have become automatized. Novices provide insights into the components of the thinking process that can become automatized but that cannot be expressed by experts because of the difficulty in describing components of automatic processing.

The CAPTAM technique is a useful tool for understanding the training needs of any task, including automatic components of thinking. The empirical and theoretical bases of CAPTAM are directly relevant to the training of those components that can become automatized (Rogers et al., 1997). This approach has been especially helpful for task domains that have heavy perceptual components but more research in complex cognitive domains will test the generalizability of CAPTAM (Orasanu, 1990). Examining complex cognitive domains (i.e., thinking) will provide some answers to the generalizability of CAPTAM. Rogers et al. (1997)

states that CAPTAM could also be used for the development of scenarios and the design of simulators.

Training Complex Tasks

For behaviors to become automatic it is only necessary to perform them, i.e., to practice them sufficiently. But that does not mean that expertise will inevitably be acquired simply through extended uncontrolled practice - only automaticity will be acquired. That may be enough with simple tasks that are easily performed in a correct manner, but for complex tasks such as thinking, it is important that the practice entails performance in a manner consistent with expertise. Schneider (1985) provides six fallacies associated with training high-performance skills (i.e., air traffic controllers). The following is a list of the fallacies and further explanation concerning them.

1. Practice makes perfect. Consistent practice is a major component of developing automaticity but Schneider suggests practice alone is not sufficient for the development of high-performance skills. For example, if participants practice a digit-span for weeks, participants who do not consistently group the digits show little improvement in their ability to maintain information in memory (Chase & Ericsson, 1981).

2. The skill must be trained in a form similar to its final execution. Schneider suggests that because of the difficulty of high-performance skills, they would be developed more effectively using component training. For example, training an individual to hit an accurate shot in golf requires many components not just the club hitting the ball. For example, if the stance, grip, backswing, or follow-through are not trained then the shot will not be successful. It is not effective to attempt to train all the components simultaneously

3. Skill learning is intrinsically enjoyable, thus including extrinsic motivators is inappropriate. If the trainer believes this fallacy, then it justifies a lack of concern for motivating the participants during training. As a result, if the training fails then the trainer can place blame on the participants because they were not intrinsically motivated to learn. For example, when adding extrinsic motivators to air traffic control tasks (e.g., interesting sound effects, interesting visual display patterns, providing criterion feedback) the failure rates decreased (Schneider, 1985). Before the addition of extrinsic motivators about 30% of the participants failed to develop sufficient accuracy in the skill-acquisition experiments. After adding extrinsic motivators, failure rates decreased to less than 5%.

4. Primary goal of training is to produce exceedingly accurate performance. In air traffic control, controllers are trained to maintain optimal separation between aircraft. Training for maximal performance accuracy can be counterproductive. The goal should be to obtain acceptable accuracy on a component skill while allowing attention to be allocated to other components of the task. In air traffic control, an operator who can maintain optimal separation of only two aircraft would not be an acceptable controller. What is desired is an operator who can maintain safe separation among 10 aircraft. Training programs following this fallacy tend to produce individuals component skills well but who cannot operate well in high-workload situations.

5. Initial performance is a good predictor of trainee and training program success. Schneider states that in reality initial performance of complex skills is very unstable and often provides a poor prediction of final performance. For example, the correlation between the first and fifteenth hour of performing a simple grammatical reasoning task was .31 (Kennedy, Jones, & Harbeson, 1980). As a skill becomes more complex, more novel, and requires longer training times, correlations decrease between initial and final performance.

6. Once the learner has a conceptual understanding of the system, proficiency will develop in the operational setting. This fallacy is related to the idea of possessing declarative knowledge but not procedural knowledge or experience. For example, in air traffic control, the classroom teacher describes the aircraft performance characteristics. However, the student may not know what those performance characteristics look like on the radarscope. As a result, many students need a great deal of experience with the system after they have learned to conceptualize it accurately in the classroom.

Summary

The major finding within the literature was that consistent practice at some level of a task leads to automaticity. Key research efforts incorporating that finding are Shriffrin and Schneider's (1977) examination of the effects of VM and CM and Anderson's (1982, 1987) use of consistent postulate sets in the solving of geometry proofs. Automaticity facilitates the development of expertise as displayed in: the ability to multi-task, increased speed of performance, increased accuracy of performance, resistance to environmental stressors, and greater retention. Another finding is that in higher-order tasks, such as thinking, there is usually a combination of controlled and automatic processing. The problem is determining which components require controlled thinking and which components can become automatized. Nine principles, along with CAPTAM, were presented as a means of identifying consistencies within a task and then training these consistencies to levels of automaticity. Also, a definition was presented as a means of measuring the extent to which tasks or the components of tasks are automatic or controlled. Therefore, one can determine if a task or component of that task is automatic and then use the nine principles along with CAPTAM to identify and train the consistent aspects of the task.

It was further found that the benefits of automaticity appear to be consistent across perceptual, motor, and cognitive tasks. That is, the features of automaticity: the ability to multi-task, increased speed, increased accuracy, resistance to environmental stressors, greater retention, etc., appear to be consistently found across different types of tasks. However the methodologies used to train tasks to automaticity are very different across each type of task. For example, perceptual studies have utilized the visual-search paradigms and vigilance tasks, while motor studies have implemented implicit learning or overlearning strategies, and cognitive studies have used problem-solving methods (ACT*) for assessing automaticity.

The literature also points out that automaticity in motor-skills may operate slightly differently than in perceptual or cognitive areas. The literature has suggested that motor automaticity may operate as a level of control theory, while automatic perceptual/cognitive skills may operate as a level of processing theory. An automatized motor-skill may operate at a level

not associated with awareness, or not directly under conscious control, while automatized perceptual/cognitive tasks involve the extent to which information has to be processed to be understood.

Evidence was provided that suggests automaticity may extend to goal pursuits. If a person pursues the same goal in the same situation, then that goal pursuit will start to be automatically paired with features of the situation and pursued. It was also reported that automaticity develops as a result of consistent exposures to a situation or scenario as in the formation of cognitive scripts. Anderson (1982, 1983, 1987, 1992) reports on automaticity from a procedural view; controlled processes result in automatic ones through the procedures of compilation and strengthening. Another account for the development of automaticity was through memory components. The instance theory stated that individuals build up instances and are able to quickly refer back to them, while the skilled-memory theory stated that through meaningful encoding the retrieval of information is speeded up.

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